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The evolution of Public Safety Communications in Europe: the results from the FP7 HELP project

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***Abstract*— This paper describes the results from the FP7 HELP project, which investigated the potential of emerging wireless communication technologies and potential synergies between mobile public safety and commercial networks to enhance the communication capabilities of public safety users. The paper identifies the current trends and challenges for wireless communications in the public safety domain, the potential solution frameworks identified in the HELP project and an economic analysis to show the benefits in terms of cost saving. The paper also describes the related research activities of the European Commission in this area.**

Note: The views expressed are those of the authors and cannot be regarded as stating an official position of the European Commission.

I. INTRODUCTION

Wireless communications technologies provide very important capabilities to public safety officers in various operational scenarios, where timely coordination is crucial, fixed communications may not be available and support for mobility is needed.

The evolution of Public Safety (PS) operations has created the need for applications which rely more on data connectivity rather than pure voice services. Data-intensive multimedia applications have a great potential to improve the efficiency of disaster recovery operation. Examples of required mobile data applications are video on location, mobile office applications, downloading/uploading of operational information from/to control rooms to/from field units, online database enquiry. A list of potential applications and the related technical requirements is available in [1].

The current dominant wireless communication standards (e.g., TETRA, TETRAPOL, APCO-25) provides a rich set of secure voice services, narrowband data connectivity but they do not offer broadband connectivity to support the applications identified above requiring bit rates as high as 1Mbps or more. TETRA TEDS [2] has been developed to supply public safety organizations with wideband data connectivity (i.e., 100 Kbps-1Mbps) and in some European countries, spectrum bands have been allocated to support this standard [3] but these bands are not harmonized yet. While TETRA TEDS represents a very important step in providing greater capabilities to public safety organizations, the technological gap between current PS communications systems and commercial ones is growing, even if it can be argued that this gap is partially justified by different business and operational requirements.

The increasing financial constraints on the government budgets may also hamper the evolution of PS communication technologies and the deployment of new communication infrastructures.

Another significant challenge for the future deployment of PS broadband services is the allocation of radio frequency spectrum. The difficulty is that suitable spectrum bands needed to build cost-effective PS networks with broadband capabilities are the same highly valued bands demanded by the market to provide commercial wireless communications.

Based on these observations, it is evident that more efficient and effective advanced wireless communication solutions than today's systems are needed. Whilst this generic challenge has always been present in the PS domain, recent political and operational evolutions in Europe are calling for major attention to this critical aspect. Political evolution is pushing for an increased collaboration among PS organisations of various nations of Europe. As pointed out in [4], there is an increasing need for harmonised procedures, technologies and spectrum allocation for PS communications at European level.

This paper has the following structure: Section II briefly describes the potential applications, which can drive the need for data connectivity. Section III identifies the main pillars of the proposed solution framework and describes the main design and architecture concepts. Section IV provides a techno-economic analysis. Section V describes other relevant projects and activities by the European Commission in this domain. Finally, the conclusions section completes this paper.

II. OPERATIONAL SCENARIOS AND APPLICATIONS

Public Safety organisations support a variety of tasks and operate in various scenarios, which have different features and operational requirements. A single organization can fulfil more than one task including Law Enforcement, Emergency Medical and Health Services (EMHS), Border Security, Protection of the environment, Fire-fighting, Search & Rescue and Emergency Crisis.

Public Safety organisations can operate in various contexts/areas:

- *Border area*, where the main focus is to address threats like illegal immigration and smuggling.
- *Urban environment*, which identifies a city or a densely urbanised area of limited size. This scenario has usually high density of people and presence of buildings, which can impact the performance of wireless communication systems.
- *Rural environment*. Identifies an area, which is not densely urbanised like countryside, mountains, hills or forest areas. The area of operations can have a wide geographical extension and radio coverage is an important requirement.
- *Critical facilities (Port, Airport)*. A port or airport may have similar features to the urban environment and border area with the presence of critical facilities (e.g., air traffic control tower) or dangerous materials (e.g., deposit of inflammable substances).

Both [1] and [5] have identified applications, which require broadband or wideband connectivity to support the operational capabilities of public safety officers in the response to large disasters or emergency crisis. A list of potential applications is provided in Table 1. These applications will be needed beyond existing services like push-to-call and end-to-end security.

Application	Description
Verification of biometric data	PS officers may check the biometric data of potential criminals (e.g., fingerprints) through mobile devices and transmit it to the headquarters.
Wireless video surveillance and remote monitoring	A fixed or mobile sensor can record and distribute data in video-streaming format, which is then collected and distributed to PS control centres.
Automatic number plate recognition	A camera captures license plates and transmits the image to PS headquarters.
Documents scan	PS officers can scan and verify a document like a driving license from mobile devices.
Database checks	PS officers can retrieve data from remote databases of control centres.
Location/Tracking for Automatic Vehicle/Officer Location. Situation Awareness	The public safety officer has a GNSS (e.g., GPS) position localizer on the mobile devices and positions are sent periodically to the headquarters to organise operations in an efficient way.
Transmission of Building/Floor plans	In case of an emergency crisis or a natural disaster, PS responders may access the layout or floor plans.
Monitoring of Public Safety officer	Vital signs of PS officers could be monitored in real-time by a control center.
Remote emergency medical service	Medical personnel can remotely support PS officers assisting wounded persons.
Sensor networks	Sensors networks could be deployed in a specific area and transmit images or data.

Table 1. List of potential public safety applications.

III. SOLUTION FRAMEWORK: SYSTEM DESIGN PILLARS AND ARCHITECTURAL VIEW

To support the applications presented in Table 1 and the peaks of traffic demand in the aftermath of a major crisis, the FP7 project HELP proposes a solution framework targeted to create and exploit synergies of composite radio systems encompassing commercial and dedicated PS technologies and networks. The proposed solution framework significantly strengthens the role and commitment of commercial wireless infrastructures in the provision of PS communications. The reason is that a single dedicated infrastructure may not provide adequate services and capacity in case of a major crisis or large natural disaster.

The solution framework is based on the exploitation of *network sharing* and *spectrum sharing* principles and the adoption of Long Term Evolution (LTE) technology (more details on LTE technology are available in [6]) for mobile broadband PS applications. *Network sharing* refers to the shared use of a network, or a part of it, by multiple users. Different types of services for different user organisations may be provided by one or several network operators, which may have a different degree of control over the shared network resources. *Spectrum sharing* is a term usually used to describe co-existence with an incumbent radio-communications application (-s) within the same frequency band as proposed for new application(s).

A. ADOPTION OF LTE FOR PS

Technological advances in the commercial domain have led to top-of-the-line radio technologies able to achieve performance levels close to Shannon's bound. The state of the art of commercial wireless technology evolution is LTE mobile broadband technology, currently positioned to be the dominant technology in future commercial mobile networks. LTE is part of the GSM evolutionary path for mobile broadband, following EDGE, UMTS, HSPA and HSPA Evolution (HSPA+). The adoption of commercial mainstream LTE technology to deliver increasingly data-intensive applications demanded by the PS agencies is getting a strong momentum among the PS community. As a matter of fact, in January 2011, FCC in US adopted a Third Report and Order (Order) and Fourth Further Notice of Proposed Rulemaking (FNPRM) to support the build out of a nationwide broadband network based on LTE Release 8 [7]. In February 2012 the US Congress passed a legislation that has led to the creation of the First Responder Network Authority (FirstNet) charged with overseeing the deployment and operation of a nationwide LTE-based PS network. Also in Europe, LTE technology is increasingly backed by the PS community and considered within European Telecommunications Standards Institute (ETSI) as a possible broadband technology to be integrated with TETRA [8]. The use of LTE technology for broadband PS has also been endorsed by many stakeholders contributing to CEPT Project Team FM49 started in September 2011 and tasked to identify and evaluate suitable bands for European-wide harmonisation of spectrum for PS [9]. The adoption of LTE for mobile broadband PS is also backed by TETRA and Critical Communications Association (TCCA) (former TETRA Association) [10]. In March 2012, TCCA has established a Critical Communications Group (CCG) to drive forward the creation of mobile broadband solutions for Mission Critical users. The main technology the group will be promoting is LTE and the first task of the group is to define requirements for the LTE standardisation in the framework of the 3GPP.

B. NETWORK SHARING

A wide consensus exists among PS users on the need of dedicated PS Networks (PSNs) for mission-critical communications since commercial Public Mobile Networks (PMNs) are not considered to provide the degree of service availability, reliability and security required for PS operations. Nevertheless, the huge investment required to roll out nationwide dedicated PSNs may not be deemed convenient or even affordable for some public administrations in the future. While some countries can deploy new dedicated PSNs for broadband PS services with nationwide coverage, others may decide to cover only some critical areas with dedicated infrastructures or even rely exclusively on commercial networks for the provisioning of PS broadband. The adoption of LTE technology in the PS domain is a key facilitator to create synergies between PSNs and PMNs networks. In this context, the coexistence of dedicated LTE-based PSNs and PMNs for mobile broadband PS communications services is expected to be commonplace in most plausible future scenarios, as illustrated in Figure 1. Legacy TETRA/TETRAPOL networks are also expected to be a cornerstone of future PS networks for mission critical voice services for the next 10 years or more. Therefore, multi-network solutions are definitively required involving dedicated and commercial networks as well as legacy PMR networks. Such solutions should enable, as reflected in Figure 1, getting access to specific PS services (e.g. online secure access to databases located in PS core infrastructures) while connected to a commercial network as well as group call communications among PS users connected through the different networks. The adoption of multimode UE with legacy PMR and LTE radio interfaces is regarded as a pivotal element to fully exploit the potential of such a composite wireless network scenario.

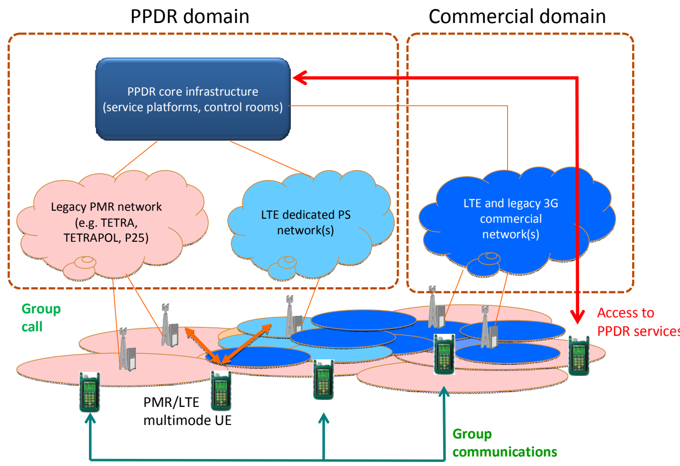


Figure 1 System view of the future PS networks

Project HELP has developed a system architecture to realise such a view of the future PS networks. The propose solution encompasses capabilities for (1) facilitate roaming and enabling PS service delivery through PSNs and PMNs in a secure and interoperable manner and (2) ensuring a proper allocation of networks' capacity to PS users according to established prioritisation policies. The key network elements and interfaces of proposed system architecture are depicted in Figure 2.

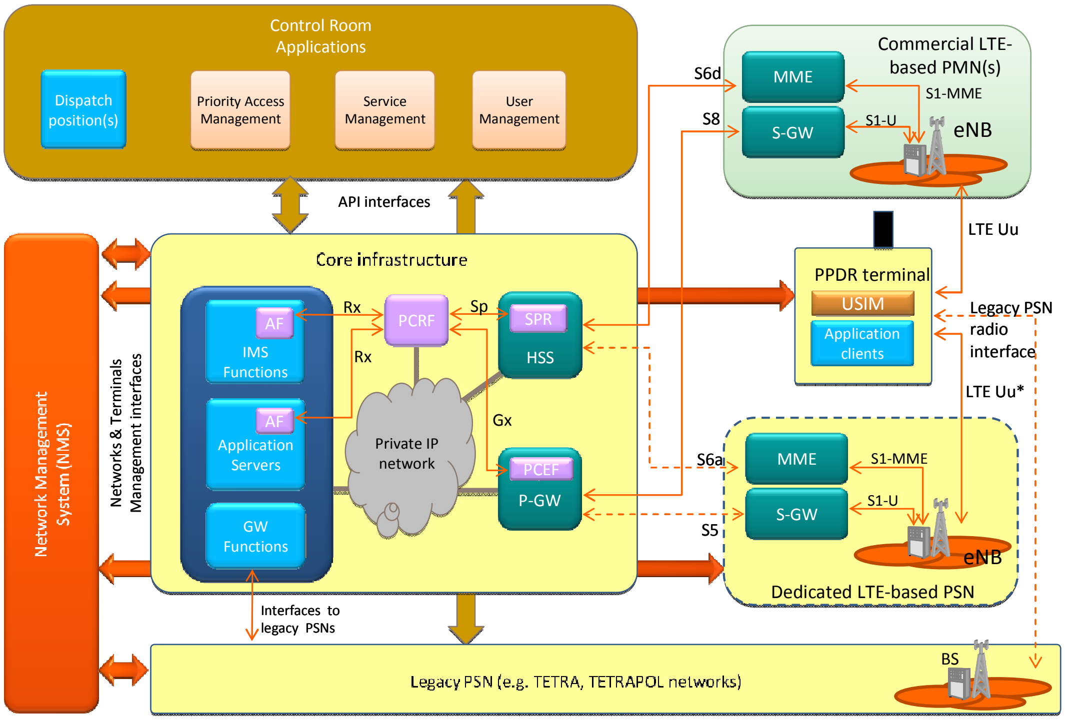


Figure 2 System architecture

The system architecture is sustained in a core infrastructure that consists of 3GPP IP Multimedia Subsystem (IMS) functions, application servers and a given set of 3GPP network components (i.e. Home Subscriber Server [HSS], Policy and Charging Rules Function [PCRF] and Packet Data Network Gateway [P-GW]), all interconnected by means of a private IP network. This core infrastructure is used to provide PS services to users in the field equipped with LTE-enabled PS terminals through a number of dedicated LTE-based PSNs and/or commercial PMNs interconnected by means of standardised 3GPP interfaces. Infrastructure sharing models can be applied in the deployment of the PSN access networks. The operation of the core infrastructure, along with the dedicated PSNs, is to be managed by a PSN operator through a Network Management System (NMS). The core infrastructure also embraces the gateway (GW) functions needed to interwork with legacy network infrastructures.

Keeping control of the PS subscription information is essential to tactical and operational PS managers since it allows PS users to completely manage the user provisioning process (e.g. activation/removal of subscribers) as well as setting up required subscriber capabilities (e.g. subscriber service profiles). Access to a LTE network is dependent on a subscription to an operator. A subscription provides the user with, among others, a subscriber identity (i.e., IMSI) and security credentials (e.g., secret keys) needed for authentication and authorisation purposes within network access control procedures. On the terminal side, this subscription information is stored in the Universal Subscriber Identity Module (USIM) module. On the network side, this information together with other subscription-related information such as service profiles (e.g. default QoS settings) are centrally handled within the HSS database of the operator. The envisioned solution considers that PS users will deploy their own HSS as part of the core infrastructure and issue and control their own USIM cards. In case that no dedicated LTE-based networks are rolled out, the proposed solution can be seen as a possible realisation of the Mobile Virtual Network Operator (MVNO) model in which the network operator in charge of PS service provisioning relies on the network capacity offered by commercial operators.

The proposed solution also considers that the PS core infrastructure will integrate its own dedicated P-GW. This provides a secure access to the PS core infrastructure and allows PS users to autonomously manage the IP connectivity service (e.g. private IP address allocation). Besides, connection mobility between PSNs and PMNs without service disruption is facilitated since the P-GW serves as a mobility anchor point for PS traffic.

The possibility to ensure that important connections/calls are always established is essential for mission-critical PS communications. Preferential treatment for access to and utilisation of LTE network resources can be supported as a realisation of the Multimedia Priority Service (MPS) specified by 3GPP. MPS allows certain subscribers to obtain and maintain radio and network resources with priority in situations such as network congestion, creating the ability to deliver or complete sessions of a high priority nature. MPS is applicable to IMS based multimedia sessions as well as other data services that might not use IMS functions. The implementation of the priority treatment for MPS in LTE networks primarily relies on the proper mapping of a set of established MPS priority levels to the QoS parameters of the IP connectivity service offered by LTE. Decision-making on the appropriate setting QoS parameters for PS communications is handled by the PCRF entity placed within the PS core infrastructure.

In addition to the PCRF entity, the proposed implementation also entails the following 3GPP functional entities: Application Function (AF), located within IMS and application servers and needed for dynamic invocation of MPS and to transfer dynamic session information to PCRF (e.g. requested media types and session/application priority extracted from SIP signalling); the Service Profile Repository (SPR) that contains subscriber related information (e.g. user's MPS priority level, user's allowed services, etc.) and can be integrated within the HSS; and the Policy and Charging Enforcement Function (PCEF), located at P-GW and used to enforce the policy decisions in the user data plane (e.g. rate control, etc.). This solution enables operational and tactical PS managers in control rooms to have direct control on the priority policy applied to PS traffic.

Extensions of the system architecture to support functionalities such as dynamic spectrum management, dynamic capacity and coverage management and situational awareness have been addressed in Project HELP. These advanced functionalities enable a more efficient utilisation and distribution of communications resources to improve system response to face specific crisis situations.

C. SPECTRUM SHARING

The deployment of future dedicated LTE-based PSNs raises the issue of identifying the spectrum band(s) and spectrum management model(s) on which these networks will be deployed and operated. Even though the inherent spectrum flexibility associated to LTE technology (i.e., LTE can be exploited in different frequency bands, using different transmission bandwidths -from around 1 MHz up to 20 MHz- and with different duplexing arrangements) will be a facilitator, political, regulatory and economical facets will have greater influence on the final solutions to be adopted.

The introduction of dynamic spectrum management functions is believed to be an essential step towards achieving enhanced capacity in emergency scenarios, enabling better PS communications and, ultimately, improving overall spectrum utilisation [11]. The following spectrum sharing models for PS communications have been identified and analysed in the FP7 project HELP:

1. Dynamic transfer of exclusive rights of use, where spectrum access is restricted to the user that holds the spectrum rights of use but these rights can be exchanged among different users for a limited time or a limited space. This option embraces also the concept of Licensed Shared access (LSA) where users are granted rights to utilise parts of a given spectrum band in spatial or time domain that are unused by an incumbent user, upon agreed terms and conditions defined with the incumbent.
2. Secondary access sharing models, where a primary user holds exclusive rights of use for a given spectrum band (i.e. licensee) but secondary users can access the spectrum in an opportunistic whenever the primary user is not disturbed.
3. Collective use of spectrum (CUS), where a number of independent users and/or devices are authorised to use the same range of frequencies at the same time and in a particular geographic area under a well-defined set of conditions.

The feasibility and usability of each sharing model for PS communications primarily depends on the type of users involved in the sharing framework as well as the kind of applications (mission critical/non-mission critical). The adoption of a sharing model is also dependent on the development of suitable technologies and regulatory frameworks. In some cases, the technical requirements for specific functions (e.g., spectrum sensing case of models built upon CR technologies) may be difficult to implement with existing technological capabilities (e.g., computing/processing power).

Furthermore, international, European and national spectrum regulations must be modified to permit the deployment of some of the sharing models. In this context, Project HELP advocates for a hybrid solution for wide area coverage based on the joint exploitation of both dedicated and shared of spectrum for PS. The dedicated spectrum will be exclusive use spectrum enough to satisfy regular PS operational needs. In addition to this core spectrum, the proposed solution also considers the exploitation of shared spectrum to face a surge of capacity demand during an emergency situation.

IV. TECHNO-ECONOMIC ELEMENTS

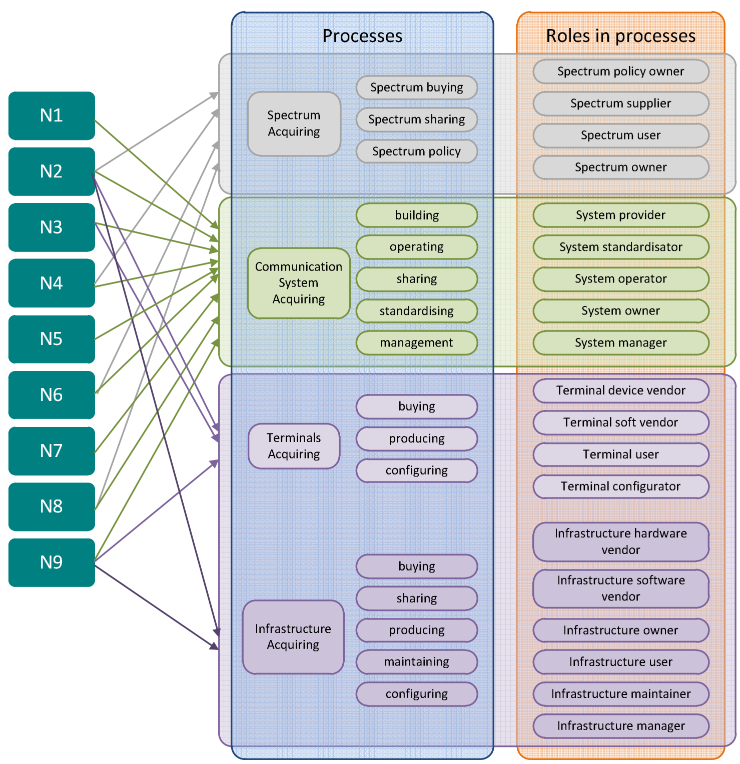
To be able to analyse the possible impact on the market of the novel solutions developed in Project HELP, a generic model of the current market has been developed ("As Is Analysis"). Using classical tools typical for market segmentation, the following questions have been addressed taking into account Project HELP's specific aspects:

- What does the customer need?

- What are the processes required to address customer needs?
- What are the roles on the market related to the processes?
- How are the roles assigned to the key market players on the current market?
- What are the actual trends on the market?

Figure 3 presents an overview of communication needs (i.e., the table) captured as a result of the analysis of the key-stress areas, denoted as focus areas, within the operational scenario considered in Project HELP. Then Figure 3 presents a mapping of user communication needs to processes required to deliver the communications services, and the roles in the service delivery chain, which have been identified exploring the business processes. The study has been done on strategic level defining the domain of further detailed analysis related to the novel technology. Please note that also alternative, currently not implemented (e.g. spectrum or infrastructure sharing), solutions have been taken into account. Each of the processes is a method that fulfils one or more needs whereas a role presents an activity related to the particular process that can be played by one or more market players. Processes and roles have been specified according to the Project HELP defined needs and are split into three groups: (i) spectrum utilised for communication purposes, (ii) overall communication system, (iii) physical devices as terminals and network infrastructure elements.

Knowing the answer to the questions defined above, the authors evaluated the technical solutions resulting from the work on Project HELP solution framework ("To Be Analysis"). The final conclusion is optimistic - the defined solution framework addresses all needs of Public Protection and Disaster Relief (PPDR) users, indicated by the project consortium. Additionally project HELP solution framework builds a toolset making the smooth introduction of the LTE technology into PS ecosystem possible, letting the PS community benefit from the synergies in composite radio systems. Allowing the interoperability with legacy technologies (e.g. TETRA), project HELP solution framework lets the PS community start a smooth process of migration, based on coexistence of both technologies. The benefits of the project HELP solution framework do not only address end users needs, but they also have economic foundations.



Needs description	
N1	Voice communications as a priority
N2	Broadband services
N3	Back-to-back and network communication for first responders
N4	Dedicated channels for each emergency service and tactical-level between supervisors of different PS services at the scene
N5	Mobile control units need to transmit data back to strategic-level command centres
N6	Tactical-level communications channels will be required to co-ordinate existing resources by supervisors of different PS services at the scene
N7	Communication links between arriving support units and other PS services
N8	Communications between Tactical-level command units and their out-of-area control centres and those at or around the scene of the incident
N9	Communication flows between operational units/control centres shall be re-established with the minimum disturbance

Figure 3: Processes & roles

Analysis of customer's needs is a basic step to describe the market, understand the behavior of the key market players and analyse the processes related to the service delivery.

Project HELP identified the following main benefits and considerations:

- *Leveraging economies of scale associated with commercial technologies.* The adoption of commercial technologies for PS is expected to bring economies of scale on those parts that add the most cost to PS equipment. Some studies [12] anticipate that the components that add the highest customisation costs (i.e. operating system, baseband chipset and Radio Frequency chipset can be 100% leveraged so that the cost of PS devices are to be close to the cost of unsubsidized commercial devices. Nevertheless, these expected benefits are still to be proved in practice and they are put into question by the PS community [13].
- *Cost considerations for the deployment of dedicated PSNs.* The deployment of dedicated networks for broadband PS, though being the preferred approach by the PS community, may not be economically affordable by all national administrations. The quantification of the costs of a nationwide broadband PSN has been the subject of several studies, most from the USA. A possible model to estimate the cost for such a network is developed in [14]. Additional information in this regard is also provided in [15]. Remarkably, the support of data services dramatically increases the number of cell sites required and so the overall network cost. Network cost is highly sensitive to input parameters such as coverage area signal reliability, building penetration margin, aggregate capacity required in emergencies, highest user data rate required, population/area build-out requirements and available spectrum band.
- *Cost savings by infrastructure sharing* One possibility for cost savings in the deployment of dedicated PSNs consists of exploiting infrastructure sharing with commercial partners. This approach is the one behind the incentive-based partnership model promoted by FCC within the National Broadband Plan (NBP). The key motivation behind this model is the deployment of the PS dedicated network based on marginal cost of adding a new radio access network for public safety to an existing tower or site, which already has backhaul to a functioning core network, and hardening the site, as opposed to the deployment of a stand-alone network where full cost for PS capabilities have to be accounted.
- *Cost saving by network capacity sharing* Sharing of the network capacity among PS and commercial can result in further cost savings as opposed to rolling out separate networks for each type of users. The key motivation behind such an approach is that PS users do not use all of the available capacity since PS communications systems needs to be designed under worst-case capacity assumptions and most of the time these large-scale incidents are not taking place. This implies that if commercial and PS users were to share capacity, most of the time the overall capacity will be practically available for commercial traffic (excepting that capacity needed for PS routine operations) while PS users will be allowed to use a higher fraction of the overall capacity to satisfy increased capacity requirements that might arise in an emergency response.
- *General considerations on spectrum costs* An estimation of the economic benefits associated to the improvement of the overall effectiveness of PS response due to the allocation of additional dedicated or shared spectrum is hard to undertake. Existing analysis [16] intended to assess the economic benefits obtained from use of PS spectrum are mainly focused on discussing cost estimates per incidents/disasters and, on the basis of the impressive numbers arisen, claim that improved PS arrangements can turn into significant savings as long as the number of incidents and their impact in lives and properties can be reduced. On the other hand, an element that is easier to estimate and that is expected to significantly impact on decision-making processes within spectrum regulatory authorities is the so called opportunity cost of the spectrum. The opportunity cost is a way of pricing the value of a given spectrum block. One way to assess the opportunity cost is to estimate how much a buyer would have been willing to pay to use that spectrum for its most promising alternative use [16].Therefore, considering that the most promising spectrum to be used for broadband PS is the same spectrum that commercial mobile operators are willing to use, a good estimate of the opportunity cost can be derived from the monetary sums offered by mobile operators in the auctions to assign spectrum for mobile communications. As illustrative figures, recently operators paid around 0.5€ /MHz/ POP and 0.73€ € /MHz/ POP for 800 MHz spectrum in Spain and Germany, respectively. The value of spectrum below 1 GHz can be between 33 and 10 times higher than spectrum in 2.6 GHz. Undoubtedly, the allocation of spectrum for PS use is key for building dedicated PS network as well as finding synergies with commercial players. 20 MHz of spectrum in 700 MHz band for

Broadband PS is already allocated in the US:4.17 $/MHz/pop were paid by MNOs in the top 20 areas (US average was US$ 1.18) for 700 MHz spectrum).

- *Economic impact of mechanisms for dynamic coverage & capacity*
  Costs that need to be incurred by MNO to implement automatic coverage hole detection and positioning are mainly limited to software costs. GPS receiver embedded in the nowadays smartphones is almost a must-have feature that makes these modules very cheap. Costs to support coverage hole compensation through network parameters readjustment account for the Remote Electrical Tilt (RET) antenna system units, higher price of power amplifiers and dedicated software. Implementation of the RET controlled antennas in the network allows a MNO to save approximately 20% of CAPEX. Support of deployable equipment also reduces MNO CAPEX. Additional costs reduction can be achieved through a renting process.

V. Security Research Programme by the European Commission

The technical solutions proposed by Project HELP can be integrated in a future overarching organisational and procedural framework, which is an evolution of existing frameworks. As with other technologies used in the PS domain (e.g. decision support, GIS), telecommunications are used to support the operational capabilities of PS users and they should not be a service on its own.

Project HELP firmly believes that the conception and development of a European Crisis Management operational framework should not be decoupled from the evolution of PS communications capabilities. On the one hand, operational procedures for crisis management should establish requirements on expected PS communications capabilities. On the other hand, advanced PS communications system capabilities can improve/modify working practices in crisis management.

The European Commission, through the Framework Programme 7 (FP7) has funded various projects in the area of wireless Public Safety communications. Only the most recent projects are identified in this paper:

- The EULER project [17] applied Software Defined Radio (SDR) technology to mitigate the lack of interoperability in joint military and public safety operational scenarios. The technical solution, adopted by the EULER project is based on SDR and the EULER Waveform (EWF) to provide a broadband wireless backbone, which can be used to transport data among heterogeneous networks and end-users. Security aspects are also addressed. EULER did not consider LTE standards and technologies, but the concept of SDR fits very well with the need for a multi-mode platform, which can communicate using different wireless communication standards.
- The FP7 DITSEF [18] (Digital & Innovative Technologies for Security & Efficiency of First responder operations) will provide a self-organising, robust ad-hoc communications networks with location information, which can be used in critical infrastructures and indoor environments where lack of radio propagation usually hamper the functioning of conventional communication systems. From this point of view, DITSEF is an extension of the concepts already described in this paper to indoor environments which were not previously addressed.
- The FP7 INFRA [19] (Innovative and Novel First Responders Application) project has the objective to research and develop novel technologies for personal digital support systems, as part of an integral and secure emergency management system to support First Responders (FR) in crises occurring in Critical Infrastructures (CI) under all circumstances. In this context, the results of INFRA can be integrated with the results of the other projects.

Beyond the single FP7 projects, the European Commission DG ENTERPRISE has strongly supported an integrated policy for the security industry at European level. As described in [20], the Commission considers that the development of 'hybrid standards', i.e. standards that apply both to civil security and defence technologies, should be actively pursued in areas where technologies are the same and application areas are very similar. In this context, a mandate for reconfigurable radio systems technologies has been recently issued. The mandate addresses commercial, public safety and military domains, with the effort to identify synergies when feasible. The new standardization mandate was the main focus of the workshop hosted in the facilities of the Joint Research Centre (JRC) of the European Commission in Ispra, Italy on the 17^{th} and 18^{th} of November 2011. The workshop was organized by EC DG ENTR, European Defence Agency (EDA) and EC DG JRC to identify the key drivers, roadmap and actions for the standardization mandate on the basis of the input of the stakeholders (around 60 participants). In this regard, the workshop was extremely useful to identify the main inputs for the commercial, public safety and military markets.

On a similar topic, but more specifically targeted to the radio frequency spectrum management, DG INFSO (now DG CONNECT) and other DGs (DG ENTR, DG ECHO) organized a workshop on the 30^{th} of March 2011 on "The future of PPDR services in Europe". It was attended by 90 participants representing national administrations and governmental organisations responsible for public safety tasks, spectrum regulators, equipment manufacturers and telecom operators, as well as a representative of the European Parliament. A report is available at [21].

In the commercial domain, the European Commission has been funding numerous projects on Cognitive Radio and Dynamic Spectrum Access in the FP7 ICT calls. An extensive survey of the funded projects is out of scope of this paper, but the following projects are related to the topics here discussed:

- Saphyre (Sharing Physical Resources – Mechanisms and Implementations for Wireless Networks) is making new self-organising physical layer resource sharing models, co-ordination mechanisms and a framework for infrastructure sharing;
- COGEU (COgnitive radio systems for efficient sharing of TV white spaces in EUropean context) is developing CR systems for use of TV White Spaces through the introduction and promotion of real-time secondary spectrum trading and the creation of a new spectrum commons regime and has created a very good database for TV White Spaces;
- Faramir (Flexible and spectrum-Aware Radio Access through Measurements and modelling In cognitive Radio systems) is developing techniques for increasing the radio environmental and spectral awareness of future wireless systems;
- E3 (End to End Efficiency) investigated the applications of cognition, adaptability and reconfigurability concepts to Beyond 3G (B3G) technologies. The key objective of the E3 project was to design, develop, prototype and showcase solutions to guarantee interoperability, flexibility and scalability between existing legacy and future wireless systems.

The European Commission is still funding relevant projects both in the security and the commercial sector on these technologies.

Conclusions

This paper has described a new approach for wireless communication systems in the public safety domain, which exploit the capabilities of new technologies and concepts like LTE, spectrum sharing and cognitive radio. The authors believe that this approach can provide significant benefits to public safety organisations and European citizens both from an economic and operational point of view.

Acknowledgment

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